PROPELLANT EXTRUSION DIE

BACKGROUND OF THE INVENTION

I. Field of the Invention

The present invention relates generally to the field of propellant charges, particularly propellant charges suited to be used in large or medium caliber projectile ammunition which are made up of extruded perforated stick-type propellant grains. More particularly, the present invention relates to a propellant extrusion die design that incorporates an array of perforation-forming pins but that eliminates the need for a pin plate and enables straight through propellant extrusion thereby substantially eliminating flexing of the die pins. This further enhances uniformity in perforation patterns associated with extruded perforated stick-type propellant shapes extruded through the die and the enhanced uniformity reduces the amount of unburned propellant slivers resulting at burnout. In addition, in accordance with the present invention, dies can be manufactured with pins of any desired cross sectional configuration and thus they can produce any desired perforation shapes in the propellant stick grains. Certain shapes have been found to significantly reduce propellant slivers associated with multi-perf propellant burns.

II. Related Art

The success of all ammunition rounds depends greatly upon the performance and reproducibility of the performance of the associated propellant system. In this regard, those skilled in the art have long sought to control the mass rate of gas generation with predictable progressive burns. Control of the burn has been enhanced for certain types of munitions by the use of perforated extruded stick propellant shapes packed into the munition cartridge to be fired.

Almost all extruded gun propellants have perforations

parallel to the lengthwise dimension of the extruded stick grains to provide ballistic progressivity as the propellant burns. Depending on size and application, stick propellants are normally processed with 1, 7, 19 or even 37 or more perforations (perfs) to enhance progressivity. Controlled progressivity is vital to the performance required by modern gun systems.

Stick propellant is extruded through extrusion tools in the form of extrusion dies which are designed to produce an extrudate having the desired shape including the internal voids associated with the perforations. The physical shape, of course, is determined by the requirements of the gun ammunition system. Extrusion dies of the class described are provided with die pins that are used to impart the perforations in the finished propellant grains. Typically, 7 perf gun propellant grains, for example, are provided with one central perforation and a single row radial hexagonal pattern of 6 perforations surrounding the central perforation. Other patterns including 19 perforations (a pattern of 1, 6, 12 perfs) and even 37 (a pattern of 1, 6, 12, 18 perfs) or more perforations are used in certain propellant designs.

Particular limitations regarding the production of stick-type propellant grains have resulted from limitations associated with the extruding dies themselves. Figures 1(a) and 1(b) depict top and cross sectional views of a typical 2-piece prior art extrusion die, generally at 10, which includes a die body 12 which may be heat treated tool or stainless steel and a pin plate 14 of the same material which nests in the die body at the entrance to the die when it is assembled in place. An orienting pin for the pin plate and matching recess in the die body are shown at 15. The pin plate is provided with an array of inlet passages 16 through which

propellant must be forced at high pressure (usually > 5000 psi) to be admitted to the die from a supply of propellant to be extruded upstream of the die. An array of 7 pins is shown at 18 forming a regular hexagon surrounding a central pin. The pins themselves designated as 20 are fixed to the pin plate as by being press fit into the plate in openings at 22, the remainder of the pin 20 being free and extending the length of the die body 12. The die body 12 is rather wide at the top or entrance to accommodate the pin plate and must be provided with a transitional zone as at 24 which tapers down to the size of the actual extrusion or agate area 26 which defines the cross sectional size of the stick.

Propellant entering the transitional zone 24 through the openings or passages 16, as can be seen from the drawings, is forced at high pressure to approach and converge on the pin array 18 and thus the die pins 20 from the outside at an angle that approaches perpendicular to the die pins 20. In the transitional zone 24, the propellant flows nearly perpendicular to the die pins 20 and this causes flexing of the die pins. Prior die designs which processed a specific propellant formulation and web size could make some allowances for the predicted pin flexure. However, process variation such as propellant solvent content (rheology), temperature, extrusion rate, etc. cause unpredictable variations in forces impinging the pins and, thus, changes in the pin flexure.

Variation in propellant die pin flexure has been ultimately manifested in variation of key physical dimensions such as web size and web difference (difference between inner and outer web thicknesses which are designed to be equal) in the perforated stick grains. While modifications have been made to the dies in an effort to reduce pin stress such as rounding the

transition zone and utilizing fewer, larger openings in the pin plate, they have only met with partial successes and there remains a long-felt need to improve perforated stick grain propellant extrusion dies.

SUMMARY OF THE INVENTION

In accordance with the present invention, there is provided a new extrusion die design that solves many problems enumerated above by allowing for secure placement of the die pins without a pin plate. The result is a straight-through die design that eliminates the disadvantages of using a pin plate and reduces inconsistencies in extruded propellant caused by pin flexure.

The present invention provides an extrusion die for use in producing perforated stick-type propellant which includes a die body having a central passage extending through the body, the passage having an open tapered entry cavity and an open lattice webbing structure within the body of the die spanning the central die passage. The strut members of the open lattice webbing structure extend parallel to the central die passage and divide but provide very little obstruction to the passage of material being extruded. An array of die pins for imparting perforations in material forced through the central passage includes pins each having a fixed end fixed to the lattice structure and a free end extending parallel to the passage beyond the lattice structure such that the material being extruded flows parallel to and around the pins.

The die of the invention may be formed as unitary structures from a die blank utilizing both conventional machining and electron discharge machining (EDM) techniques. Thus, after the outside of the blank is machined and holes are drilled in the blank corresponding to openings in the lattice structure, EDM may be used to

cut out the lattice web, together with the desired array of pins with great accuracy. The pins may be formed at the time the open lattice web is machined, or they may be separately fabricated and attached as by press fitting into recesses provided in the open lattice webbing itself. If separate pins are to be inserted, a slightly thicker webbing is used.

The preferred material of construction for the extrusion die of the invention is precipitation hardened stainless steel, possibly 15-5 PH or 17-4 PH stainless steel. Separately manufactured pins may be constructed of hardened tool steel. The die passage surrounding the vicinity of the pins preferably may be slightly tapered in accordance with reforming the propellant stick after it becomes segmented when it encompasses the open lattice web structure.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, wherein like reference characters depict like parts throughout the same:

Figure 1(a) is a top view of a prior art propellant extrusion die showing the top of the die pin and indicating the central pin pattern;

Figure 1(b) is an elevational view partially in section of the extrusion die of Figure 1(a);

Figure 2 is a top view of an extrusion die fabricated in accordance with the present invention;

Figure 3 is an elevational view partially in section of the extrusion die of Figure 2, taken along lines 3--3 of Figure 2;

Figure 4 is an elevational sectional view taken substantially along lines 4--4 of Figure 2;

Figure 5 is a greatly enlarged view showing one pin detail of an extrusion die fabricated in accordance with the invention;

Figure 6 is a greatly enlarged top perspective view

of the die constructed in accordance with the invention; and

Figure 7 is a greatly enlarged bottom perspective view of the die of Figure 6 showing the area of pins as integral with lattice webbing struts in the area of free length of the pins.

DETAILED DESCRIPTION

The extrusion die of the present invention will now be described with respect to a specific embodiment, however, the descriptions contained herein are intended to present examples of embodiments of the invention and examples of methods of making the embodiments of the invention and are not meant to be limiting with regard to the scope of the invention in any manner. In this regard, an important aspect of the invention involves the provision of a straight-through extrusion arrangement which eliminates the need for propellant to encounter the perforation pins from the side. By enabling extrusion directly into the web, all propellant motion is substantially parallel to the pins which is beneficial both to product quality and pin life.

Figures 2-4 depict one embodiment of the extrusion die of the invention which is depicted generally by the reference character 40. The die may be of a single piece unitary construction and includes an upstream or die body entry opening 44 which is generally tapered at an acute angle narrowing down to the entry of the main body or agate section of the die 46 which contains the open lattice webbing which includes a center 48 and a series of relatively thin radial struts connecting the center with the inner wall of the die as at 50 which form the open lattice webbing structure through which the extruded propellant passes during the extrusion process. Each of the webbing struts 50 includes an enlarged, raised shaped area as at 52 (see also Figures 6 and 7) that is in the

shape of and at the radial location of a perforation pin 54. The pins 54 preferentially end a short distance before the end of the die to prevent pin damage. A minor recess may be machined into the bottom of the die as at 56, if desired.

Figure 5 shows a greatly enlarged alternate pin detail in which a circular hexagonal array of substantially trapezoidal shaped pins 70 are machined as integral extensions of the lattice webbing struts 50 and the center pin 72 is a round press fit, separately manufactured pin. Note that the inner and outer bases of the trapezoidal pin are indicated by and are co-incident with concentric circles 74 and 76, at least the outer, longer base of each trapezoid being of an arcuate shape to coincide with the round outer dimension of propellant extruded through the subject die.

The trapezoid is one non-round shape that has been used to greatly enhance burn progressivity (by elimination of slivers) in certain propellant sticks. The use of non-round shaped extrusion pins and propellant stick grains made with them is described in greater detail in co-pending application S. N. 10/___________, filed of even date and assigned to the same assignee as the present invention, entitled "PROPELLANT EXTRUSION USING SHAPED PERFORATION PINS". That application is hereby incorporated by reference herein in its entirety for any purpose.

Figures 6 and 7 show greatly enlarged top and bottom perspective views of an embodiment of the invention which utilizes 7 round pins to create a 7-perf extruded stick. Figure 7, particularly, depicts the free ends of the pins extending beyond the open lattice webbing struts 50. As can be seen from the figures, and particularly, Figure 4, the area of the open lattice webbing between its beginning at 58 and ending at 60 is tapered. The taper

is normally between about 9° and 11°, but may be varied as desired. The taper slightly constricts the propellant that has been segmented in moving past the struts 50 of the open lattice webbing of the die so that it more readily re-forms a single stick in the lower or exit die area 62. The area 62, of course, is in the area of the free length of the pins 54. It should be noted that very little movement of the propellant is required in the direction perpendicular to the pins during the extrusion process.

The dies 40 can be made from a single piece of stainless steel first machined using conventional machining techniques where possible to achieve the desired outer surface and inner entry taper, and if desired, an outlet recess. In the case of a 7-perf system, 6 holes are then drilled in the blank corresponding to the void areas between the webbing struts and an EDM device using a wire cutout system is utilized to make the web and, if desired, the pins so that the entire device is integral with the original blank. This technique allows highly accurate web and pin structures to be produced. As indicated before, the material of the die blank is preferably heat treated stainless steel as it must be a material which is corrosive resistant when exposed to various propellant compositions, caustic cleanout material and other materials associated with processing the propellant. Such techniques are known and can create webs or pins of any desired shape or thickness.

While this technique has been found quite successful, the applicants contemplate that other hybrid techniques might also be employed. For example, the center pin is typically manufactured separately and press fit into a central tapered opening as shown at 64 in Figure 4. In addition, the radially distributed pins of

any desired shape may be fabricated separately and added to the web after other machining is completed. This requires slightly enlarged shaped areas for receiving pins as at 52 to be created on the struts of the web and press fit or other techniques employed to implant the pins such as that described for the center pin.

The straight-through extrusion die enables great improvements to be achieved in geometric stability of the pin pattern. Using the techniques of the present invention, pin flexure associated with the extrusion process has been reduced by 75-80% from conventional dies. Variations in the web thickness of propellant extruded through the dies have been greatly improved (reduced), i.e., from about 7.0%, which has been commonly encountered with prior dies, to 4% or less utilizing the dies of the present invention. The dies of the present invention may achieve a web uniformity variance as little as 2-3% in some cases. In addition, in recent extrusion tests, dies in accordance with the present invention have experienced a first pass yield of 90% or greater of usable material versus no more than 80% with prior conventional dies.

This invention has been described herein in considerable detail in order to comply with the patent statutes and to provide those skilled in the art with the information needed to apply the novel principles and to construct new such specialized components as are required. However, it is to be understood that the invention can be carried out by specifically different devices and that the various modifications, both as to the equivalent details and operating procedures can be accomplished without departing from the scope of the invention itself.

What is claimed is: